Non-Stationary Tides and SWOT

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Outline

1. Definition: What is the "non-stationary tide"?
2. Measurement: Observations of the non-stationary tide.
3. Mechanisms: What causes the non-stationary tide?
4. Four examples: How large is the SSH signal of the non-stationary tide, and where is it likely to be significant?

Definitions & Preliminaries

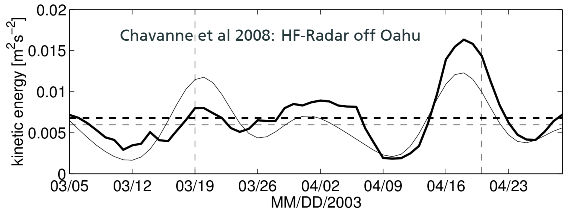
To interpret SWOT SSH observations in terms of quasi-geostrophic dynamics, it will be necessary to remove the signal caused by internal gravity waves.

The surface expression of semidiurnal and diurnal internal tides (and coastal tides) will overlap with the sub-mesoscale signals with wavelengths between 150 km and 15 km.

The stationary tide is, in principle, predictable since it is coherent with the known astronomical tidal forcing (ATF).

The non-stationary tide is that component of tidal variability which is not coherent with the ATF.

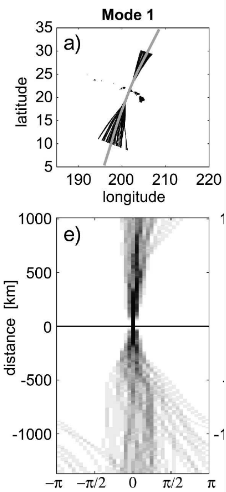
Observations of the Non-Stationary Tide



- Currents: ..., Wunsch (1977), Chavanne & Klein (2010), Kelly et al (2015)
- Stratification: (thermocline depth, steric height, acoustic travel time) ... , Mitchum & Chiswell (2001), Zilberman et al (2011), Zhou et al (2015), Kelly et al (2015)
- Tide gauges: ..., Woodworth, Ray, Jay, ...

Causes of the Non-Stationary Tide

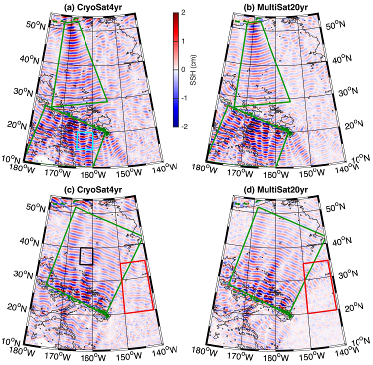
- Weak refraction: Rainville & Pinkel (2006), Park & Watts (2006), Zaron & Egbert (2014)
- Strong refraction, vertical scattering, and caustics: Dunphy & Lamb (2014), Ponte & Klein (2015)
- Generation site changes: Zilberman et al (2011), Pickering et al (2015)
- Tide/Mesoscale interactions: Avicola et al (2007)
- Tide/Frictional interactions: Kang et al (1995), Arbic & Garrett (2010), Müller (2012)

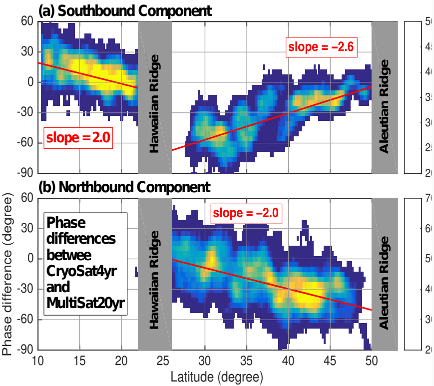


Rainville & Pinkel 2006

Non-Stationary tides example 1

MultiSat20yr (1992–2012) and CryoSat4yr (2011–2014)



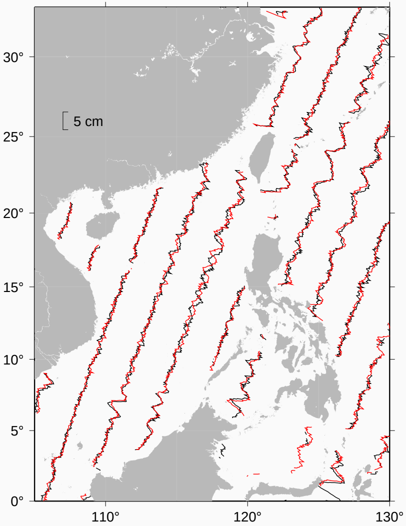


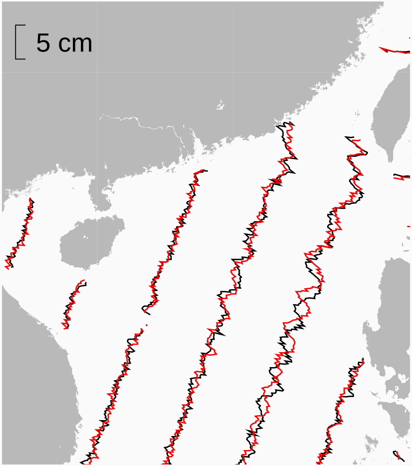
Figures 5 and 7 in Zhao Z. (2016), Using CryoSat-2 Altimeter Data to Evaluate M2 Internal Tides Observed from Multisatellite Altimetry, JGR-Oceans, in press.

0.2 cm rms change

Non-Stationary tides example 2

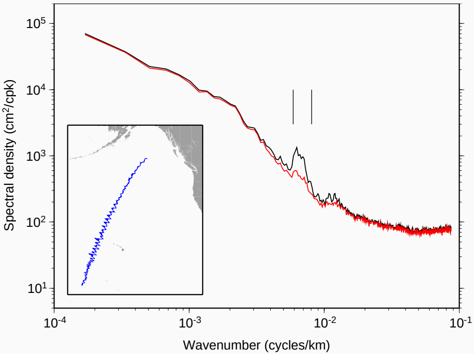
Summer vs. Winter South China Sea





Ray & Zaron, 2011

Non-Stationary tides example 3a

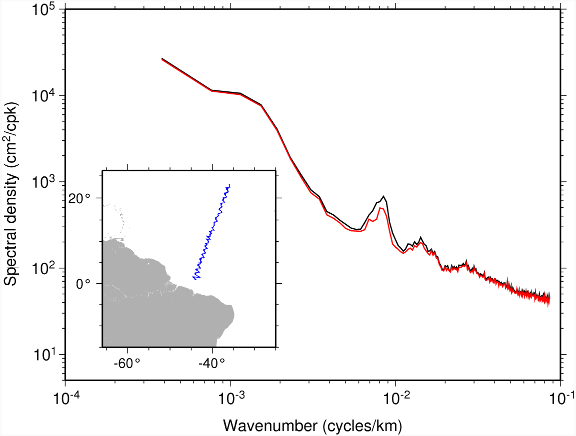


Mode-1: 1.19 cm^2 total, 0.23 cm^2 non-stationary.

Mode-2: 0.26 cm^2 total, 0.12 cm^2 non-stationary.

Ray & Zaron, 2011

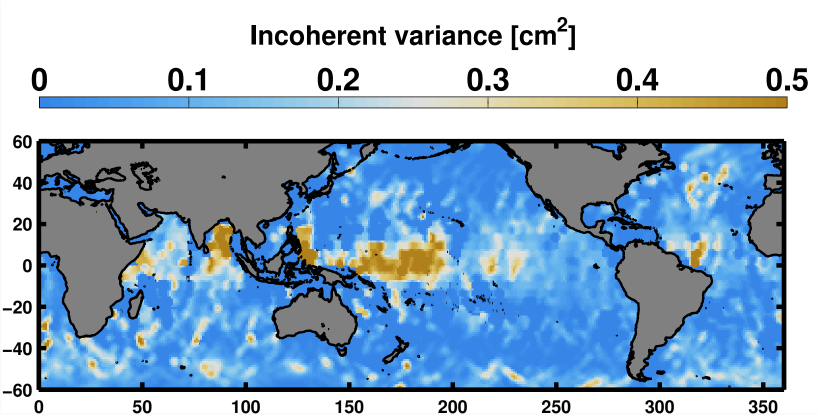
Non-Stationary tides example 3b



1.07 cm^2 total, 0.47 cm^2 non-stationary.

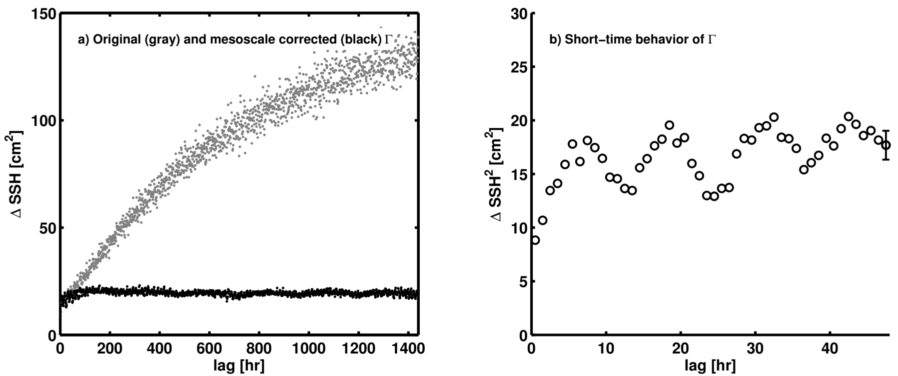
Ray & Zaron, 2011

Non-Stationary tides example 3c



[Preliminary – will be revised]

Non-Stationary tides example 4



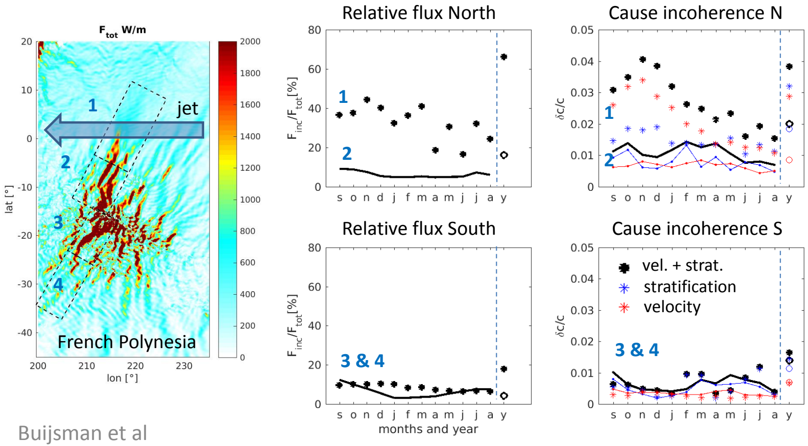
SSH difference squared and averaged over all Jason-1/CryoSat-2 crossovers.

Semidiurnal band: 1.1 cm^2 total, 0.33 cm^2 non-stationary.

Zaron 2015

Non-Stationary tides from ocean models

Semidiurnal Internal Tide Incoherence at the Equator



Buijsman et al

Summary & Implications

- Models and data are grossly consistent, 20% to 30% of baroclinic tidal SSH variance is non-stationary; likely to be 0.5 cm or smaller in the open ocean.
- There are “hot spots” where the non-stationary tide is larger, where generation sites are coincident with strong and variable currents (Amazon, Luzon Strait, etc.).
- Observability of the sub-mesoscale will depend on the spectral slope of SSH *and* the accuracy of the internal tide correction. Both are spatially variable.
- Model-based nowcasts/forecasts for the non-stationary tide are possible, in principle, but not yet demonstrated.